Oriented Core and Rockmass Classification

This tutorial demonstrates a *Dips* file which uses borehole (oriented core) data as the orientation input data. Using the information in the Extra Columns of the *Dips* file, a rock tunneling quality index Q is estimated.

This tutorial uses the file **Exampbhq.dips6**, which you should find in the Examples folder of your *Dips* installation folder.

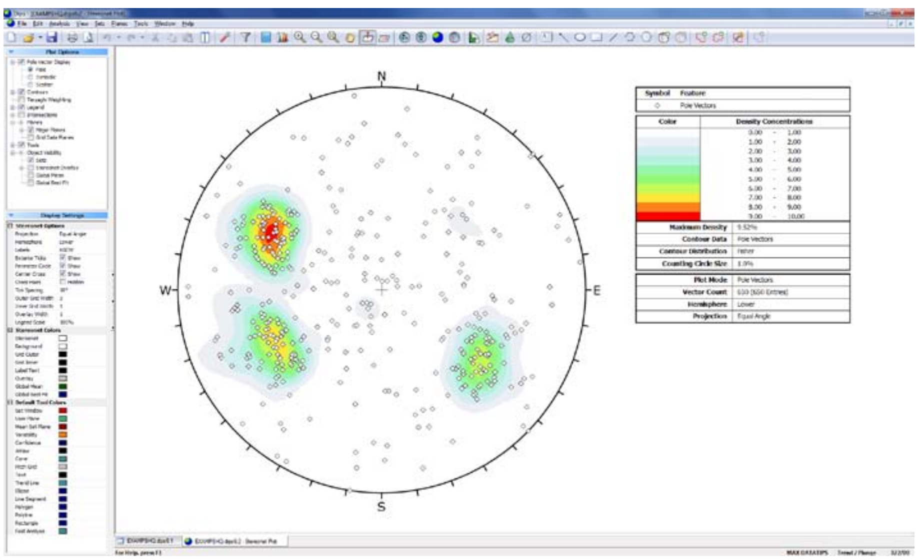
Frequently asked borehole traverse questions are discussed at the end of this tutorial.

Exampbhq.dip File

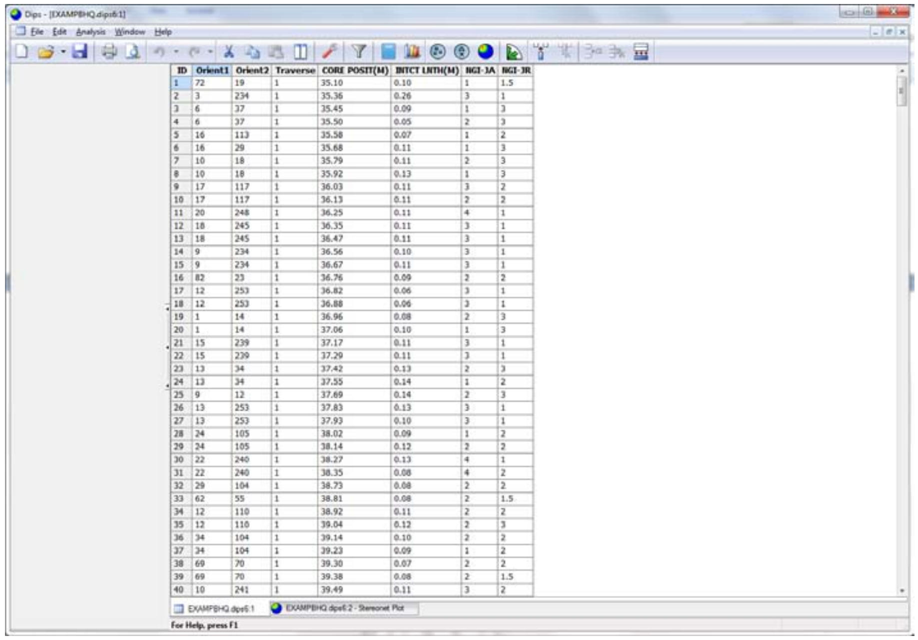
Navigate to the Examples folder in your *Dips* installation folder.

Select: File → Recent Folders → Examples Folder

Open the **Exampbhq.dips6** file. Maximize the view.



Switch to the grid view of the file using the tabs at the lower left.



ID	Orient1	Orient2	Traverse	CORE POSIT(M)	INTCT LNTH(M)	NGI-JA	NGI-JR
1	72	19	1	35.10	0.10	1	1.5
2	3	234	1	35.36	0.26	3	1
3	6	37	1	35.45	0.09	1	3
4	6	37	1	35.50	0.05	2	3
5	16	113	1	35.58	0.07	1	2
6	16	29	1	35.68	0.11	1	3
7	10	18	1	35.79	0.11	2	3
8	10	18	1	35.92	0.13	1	3
9	17	117	1	36.03	0.11	3	2
10	17	117	1	36.13	0.11	2	2
11	20	248	1	36.25	0.11	4	1
12	18	245	1	36.35	0.11	3	1
13	18	245	1	36.47	0.11	3	1
14	9	234	1	36.56	0.10	3	1
15	9	234	1	36.67	0.11	3	1
16	82	23	1	36.76	0.09	2	2
17	12	253	1	36.82	0.06	3	1
18	12	253	1	36.88	0.06	3	1
19	1	14	1	36.96	0.08	2	3
20	1	14	1	37.06	0.10	1	3
21	15	239	1	37.17	0.11	3	1
22	15	239	1	37.29	0.11	3	1
23	13	34	1	37.42	0.13	2	3
24	13	34	1	37.55	0.14	1	2
25	9	12	1	37.69	0.14	2	3
26	13	253	1	37.83	0.13	3	1
27	13	253	1	37.93	0.10	3	1
28	24	105	1	38.02	0.09	1	2
29	24	105	1	38.14	0.12	2	2
30	22	240	1	38.27	0.13	4	1
31	22	240	1	38.35	0.08	4	2
32	29	104	1	38.73	0.08	2	2
33	62	55	1	38.81	0.08	2	1.5
34	12	110	1	38.92	0.11	2	2
35	12	110	1	39.04	0.12	2	3
36	34	104	1	39.14	0.10	2	2
37	34	104	1	39.23	0.09	1	2
38	69	70	1	39.30	0.07	2	2
39	69	70	1	39.38	0.08	2	1.5
40	10	241	1	39.49	0.11	3	2

The file contains 650 measurements from 2 oriented borehole cores.

The file uses the following columns:

- The two mandatory Orientation Columns
- A Traverse Column
- 4 Extra Columns

Orientation Columns

The Orientation Columns for borehole data record **alpha** and **beta** core joint angles.

- The **alpha** angle, entered in the Orient 1 column, is measured with respect to the **core axis**.
- The **beta** angle, entered in the Orient 2 column, is measured with respect to the **core reference line**.

NOTE: see the *Dips* Help system for detailed information about recording oriented core data.

Extra Columns

The four Extra Columns record the following information:

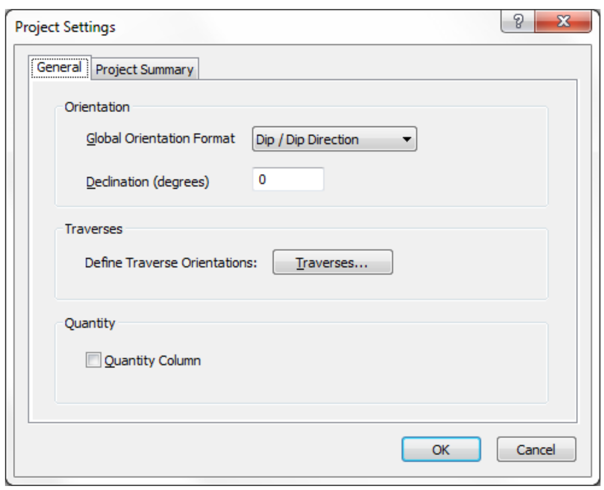
- core position from collar
- intact length (calculated in a spreadsheet from position or recorded directly) between adjacent joints
- JA
- JR

The latter measurements are qualitative indices of roughness and alteration taken from the Q Classification by Barton and can be quickly recorded during core logging. Consult any modern rock engineering text for a definition of these terms.

Let’s examine the Project Settings information for this file.

Project Settings

Select: Analysis → Project Settings

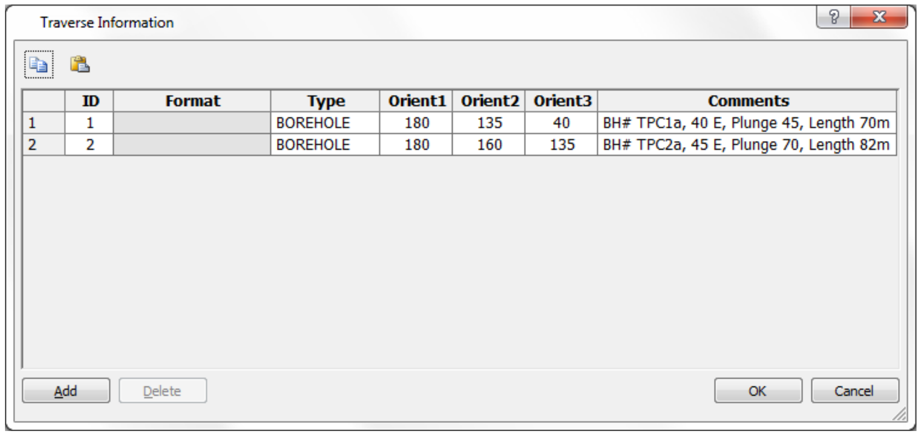


Note the following:

- The Global Orientation Format is DIP / DIPDIRECTION. However, since we are working with oriented core data, the Global Orientation Format does NOT apply to the data in the Orientation Columns which are alpha/beta core angle measurements.
- The Declination is zero in this file. Declination would, if present, be applied to the borehole trends (azimuths).
- The Quantity Column is NOT used in this file, so each row of the file represents an individual measurement.

Traverses

Let's inspect the Traverse Information. Select the **Traverses** button in the Project Settings dialog (the Traverses dialog is also available directly in the Analysis menu).



As you can see in the Traverse Information dialog, this file uses two borehole traverses. A borehole traverse in *Dips* requires THREE orientation values in order to fully define the orientation of the borehole and oriented core:

- **Orient 1** – both traverses have an Orient 1 value of 180. This denotes a reference line (along the length of the core) that is 180 degrees from the top of the core (i.e. at the **bottom** of the core as it would be in situ).

- **Orient 2** – the Orient 2 value indicates the drilling angle from the **vertical**. Traverse 1 has an Orient 2 value of 135, indicating that the borehole was drilled at 135 degrees from the vertical, or with a plunge of 45 degrees. Traverse 2 was drilled at 160 degrees from the vertical, or a plunge of 70 degrees.

- **Orient 3** – the Orient 3 value indicates the azimuth (i.e. clock-wise angle from compass north) of the **downhole** direction of the borehole. Orient 3 is 40 degrees for Traverse 1 and 135 degrees for Traverse 2.

NOTE: see the *Dips* Help system for detailed illustration of the borehole orientation requirements for *Dips* input.

Select Cancel in the Traverse Information dialog.

Select Cancel in the Project Settings dialog.

Rock Tunneling Quality Index – Q

The rock tunneling quality index Q is defined as:

Q = (RQD / JN) * (JR / JA) * (JW / SRF)

Consult any modern rock engineering text (see the references at the end of this tutorial) for more information if required.

Set the water parameter JW = 1 (dry) and stress reduction factor SRF = 1 (moderate confinement, no stress problems) for this example.

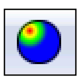
Determination of RQD

Using the intact lengths, RQD (Rock Quality Designation) can be calculated using a spreadsheet. RQD is taken as the:

Use a spreadsheet and the INTACT LENGTH extra data column to determine a value for RQD.

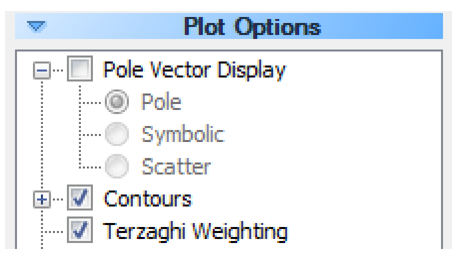
$$\frac{\text{Cumulative length of core pieces greater than 10 cm}}{\text{Total length of core}} \times 100$$

Determination of JN



JN is the joint number. To obtain a value for this parameter, let's view a Contour Plot, to determine the number of (well) defined joint sets. Select the Contour Preset toolbar button.

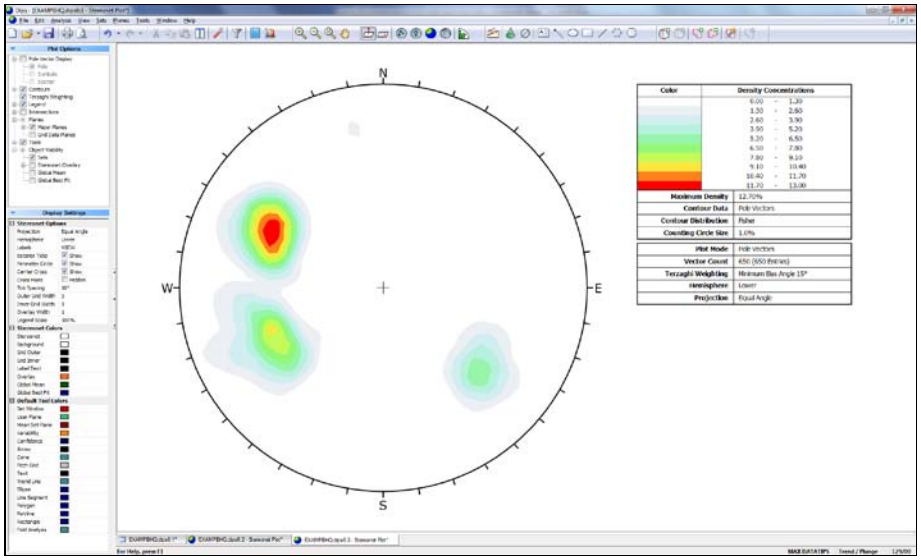
Apply the Terzaghi Weighting, so that we can view the weighted contours. Select the Terzaghi Weighting checkbox in the sidebar plot options.



NOTE: *Dips* has automatically converted the borehole alpha and beta angles to true dip and dip direction, using the borehole traverse orientations entered in the Traverse Information dialog.

View a WEIGHTED Contour Plot of the data.

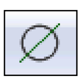
The three well defined joint sets result in a Barton JN value = 9.



The three well defined joints sets result in Barton's JN = 9.

Now use Add Set Window to determine the mean orientations of the three joint sets. (See **Tutorial 03** for details about creating Sets with the Add Set Window option.) NOTE: when you create the Sets, make sure the mean planes are displayed using the checkbox in the Add Set Window dialog. Since the Terzahgi weighting is applied the WEIGHTED mean planes are displayed, as indicated by the letter "w" displayed beside the Set ID number.

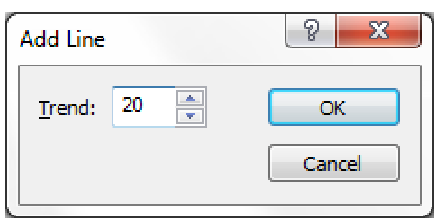
Finally, let's add a LINE through the center of the stereonet, to represent a proposed tunnel axis. Assume a tunnel trend of 20 degrees.



Select: Tools → Trend Line

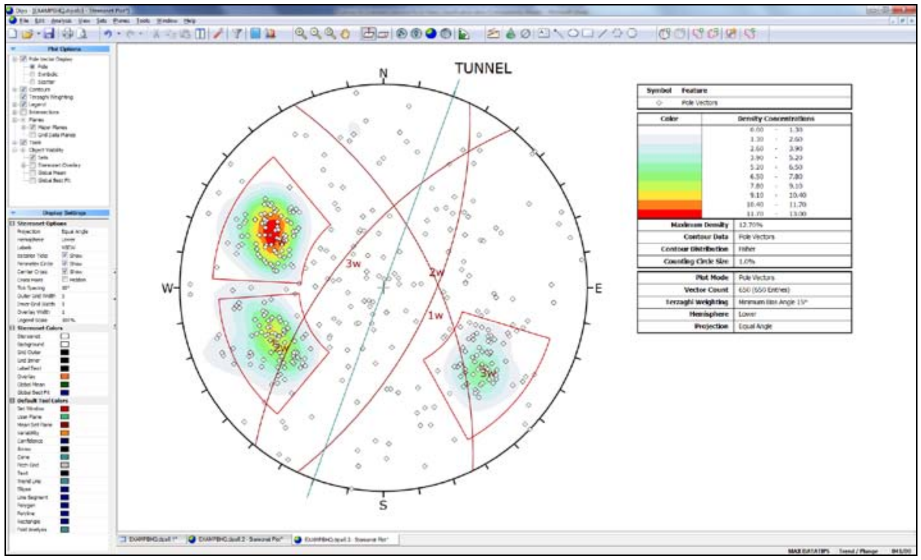
1. Place the cursor at APPROXIMATELY Trend = 20 degrees, and click the left mouse button (remember that the cursor coordinates are visible in the Status Bar).

2. In the Add Trend Line dialog, if your graphically entered orientation is not exactly 20 degrees, then enter 20 and select OK.



Turn on the display of pole vectors (in the sidebar plot options select Pole Vector Display > Poles). Use the Add Text tool to add the label Tunnel to the trend line.

*Superimpose the **tunnel axis** on the **mean joint planes** to judge the critical joint set for Q classification.*



It is not immediately obvious which is the critical joint in this case. However, it can be shown that joint set 1 is most likely to prevent any development of tension in the roof and therefore will reduce the self-supporting nature of the tunnel roof. Let us then use this as the critical joint set for Q classification. Note the sliding wedge (closed triangle in the above plot formed by the three joint sets) which appears in the roof of the tunnel.

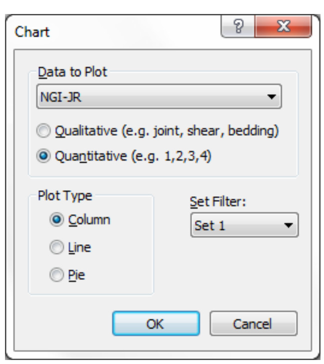
Estimation of JR and JA

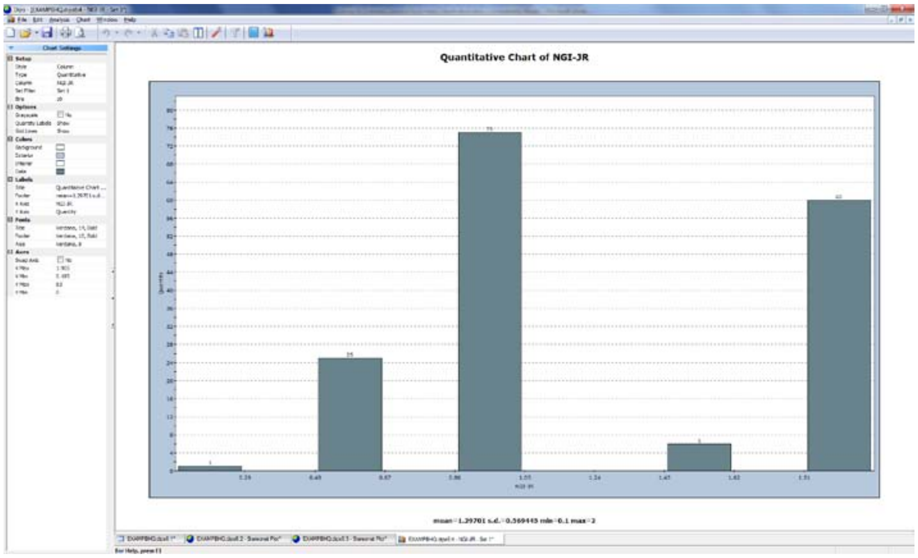
The next step is to use the Chart option to look at JR and JA. These indices can be viewed as either QUALITATIVE or QUANTITATIVE. Quantitative analysis allows a mean calculation and so is preferred.

Select: Analysis → Chart

Create Quantitative Charts of the JR and JA Extra Columns, to estimate mean values of JR and JA for the critical joint set.

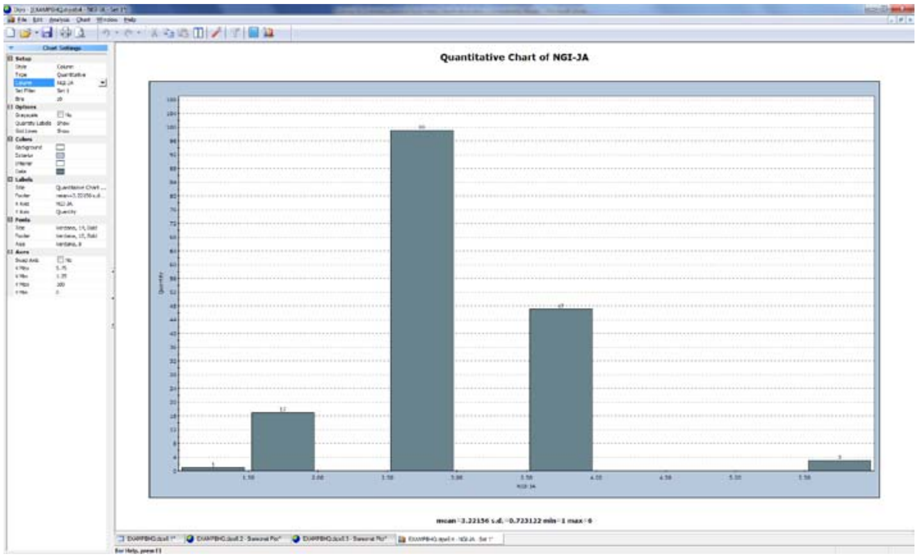
In the Chart dialog, select Data to Plot as NGI-JR, select the Quantitative button, and select Set 1 in the Set Filter. (NOTE that Set 1 in this example is the joint set at the upper left of the stereonet. If you used different Set IDs, then enter your Set ID for this Set). Select OK.





Notice the mean and standard deviation at the bottom of the Chart. The mean value of JR is approximately 1.3.

Now change the data type to NGI-JA. In the sidebar Chart Settings > Setup select Column = NGI-JA and make sure the Type = Quantitative. The mean value of JA is approximately 3.2.



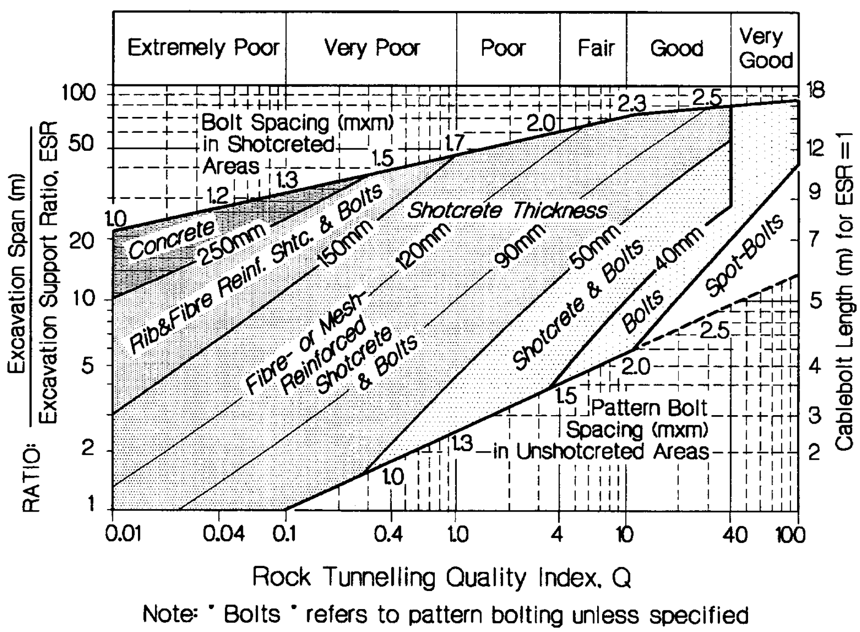
For the purposes of classification, a JR of 1 to 1.5 and a JA of 3 to 4 would be adequate in this example.

Calculation of Q Values

RQD, as calculated in the spreadsheet was 60%. Using the JN value of 9, and the upper and lower limits for JR and JA (see above), gives:

- A lower Q of (60 / 9) * (1 / 4) * (1 / 1) = 1.7
- An upper Q of (60 / 9) * (1.5 / 3) * (1 / 1) = 3.3

This range of values can now be used for further empirical support design according to Barton's design charts – see the figure below. Real values for JW may be evaluated qualitatively from borehole inflow notes. SRF can be determined from the depth of the proposed excavation according to Barton.



Tunneling support guidelines, based on the tunneling quality index Q (bolt lengths modified for cablebolting). Ref. 1, after original Ref. 3.

Frequently Asked Borehole Traverse Questions

To conclude this tutorial we will answer 3 frequently asked questions regarding borehole traverse and oriented core data processing with *Dips*.

1. How do I obtain a listing of true dip / dip direction values from oriented core data?

   Answer: use the **Process Data** option in the Analysis menu and save a new *Dips* file in the processed format of your choice.

2. Can I define a curved borehole in *Dips*?

   Answer: it is NOT possible to define a curved borehole in *Dips* as a single borehole traverse. To analyze **oriented core** from a curved borehole, you will have to divide up the borehole into an appropriate number of smaller sections, and define an individual borehole traverse for each section, assuming a constant orientation for each section of the borehole.

3. I already have processed borehole data from televiewer measurements. What type of traverse do I use in *Dips*?

   Answer: the borehole traverse option in *Dips* is strictly for processing **oriented core** data. If your borehole data has already been processed (e.g. direct measurement of fracture orientations by optical or acoustic televiewer), then you do NOT use the borehole traverse option. In this case you can define each section of the borehole as a LINEAR traverse in *Dips*, and enter the Trend / Plunge of the borehole as the traverse orientation in the Traverse Information dialog.

See the *Dips* help system for futher information.

References

1. Hutchinson, D.J. and Diederichs, M. 1996. Cablebolting in Underground Mines, Vancouver: Bitech. 400 pp.

2. Hoek, E., Kaiser, P.K. and Bawden, W.F. 1995. Support of Underground Excavations in Hard Rock. Rotterdam: Balkema.

3. Grimstad, E. and Barton, N. 1993. Updating the Q-System for NMT. *Proc. int. symp. on sprayed concrete* - *modern use of wet mix sprayed concrete for underground support*, Fagernes, (eds Kompen, Opsahl and Berg). Oslo: Norwegian Concrete Assn.